Indian Journal of Weed Science **53**(3): 275–280, 2021

Print ISSN 0253-8040 Online ISSN 0974-8164

Rice straw mulch mats – biodegradable alternative to herbicides in papaya

Sandeep Bains, Rajdeep Kaur*, Manisha Sethi, Monika Gupta and Tarundeep Kaur
Punjab Agricultural University, Ludhiana, Punjab 141001, India
**Email: msrajdeepct@pau.edu*

Article information

DOI: 10.5958/0974-8164.2021.00050.2

Type of article: Research article

Received : 3 February 2021
Revised : 26 July 2021
Accepted : 29 July 2021

KEYWORDS
Fruit yield, Mulching, Papaya, Rice straw, Weed control

ABSTRACT

Rice occupies a pivotal place in Indian agriculture. Its production leads to generation of excessive rice straw. Since straw is not utilized much, it is subjected to burning in fields causing serious environmental pollution, loss of nutrients and adverse effects on beneficial soil micro-organisms. This study conducted in Punjab Agricultural University, Ludhiana reports the effectiveness of rice straw mulching material on weed control, yield enhancement and quality improvement in Papaya (Var. *Red lady 786*). Woven mulch mats of rice straw resulted in significant reduction in weed density of broad-leaved weeds as well as grasses as compared to control besides improving fruit height (26.3%), fruit yield (31.7%), fruit colour, TSS and carotenoids in papaya. Furthermore, the biodegradable woven mulch has the capability to control weeds for 315 days *i.e.* the entire vegetative as well as fruiting period in papaya.

INTRODUCTION

In India, 50% population is engaged in farming and cultivation of agricultural products. The production of millions of tons of agricultural crop every year has subsequently increased the agricultural waste that we as a country are dealing with right now. The waste, commonly known as 'the residue' is made up of organic compounds from various organic sources like rice straw, coconut shell, sugarcane bagasse to name a few. Since the residue accumulates in large amount, it becomes extremely difficult for farmers to have an alternative access. In the process of harvesting, a humongous quantity of straw/husk is also generated which needs to be recycled in a sustainable way. The easiest way used by the farmers to dispose the remains of rice is incinerating it in the fields, which eventually pollutes the environment and cause huge loss of nutrients. Various studies have shown that incinerating stubble in the fields has been found to be a major hazard. It causes air pollution and adversely affects the organic carbon levels of soil. In northern states of the country, increase in intensity of air pollutants is found to be 20% higher than the threshold for safe air (Anonymous 2019).

Removal of stubble by burning has negative implication on soil health. The nutrients present in the stubble are exhausted while burning and farmers have to shell out extra monetarily on chemical and fertilizers to maintain soil quality. A study (Jitendra *et al* 2017) has quantified that crop residue burning in India releases approximately 149.24 million tonnes of carbon dioxide, 9 million tonnes of carbon monoxide, 0.25 million tonnes of oxides of sulphur, 1.28 million tonnes of particulate matter and 0.07 million tonnes of black carbon. These directly contribute to environmental pollution, and are also responsible for the smog in plain areas. The heat from burning of rice straw penetrates one cm into the soil, elevating the temperature to 33.8 to 42.2 degree Celsius. This kills the bacterial and fungal populations critical for a fertile soil. Burning of crop residue causes damage to other micro-organisms present in the upper layer of the soil as well as its organic quality.

We also need to understand that the burning of rice or stubble leads to the loss of key nutrients as nearly 50% sulphur, 75% potassium and 25% of the nitrogen and phosphorus is lost (Anonymous 2019). As such, stubble burning is a serious issue and it must be managed with immediate effect by opting other potential alternatives.

Solutions to the burning problem

The issue of stubble burning can be forfeited by providing stubble collecting machines (bailers) to the farmers or offering reasonable labour to reap rice. Converting stubble into mulch sheets is another innovative and environment friendly way to address the issue besides exploring its use for weed management in papaya and other fruit tress/ vegetables.

Papaya (*Carica papaya* L.) belongs to family Caricaceae and native of Mexico. Papaya is mainly grown as kitchen garden plant, but due to its nutritional importance, availability of fruits all around the year and the highest returns, it is being commercialized. Papayas are good source of vitamin A and calcium. The papaya fruits also provide folate, potassium, magnesium, copper, pantothenic acid, alpha and beta-carotene, zeaxanthin, lutein, vitamin K, and lycopenes. So, there is vast scope to increase area and production under papaya crop. The major papaya producing states in India are Andhra Pradesh (27.1%), Gujarat (23.2%), Maharashtra (7.6%), Karnataka (10.5%), Madhya Pradesh (5.4%), West Bengal (7.7%) and Assam (3.2%) due to ideal climatic conditions for its growth and production (Anonymous 2010, Suresh and Saha 2004).

Weed control is a big challenge for most of the crops, and papaya is also not an exception. Regular and frequent cultivation of the orchards destroys the physical condition of the soil, increases runoff and soil erosion besides escalating cost of cultivation. It also leads to development of *Phytophthora* disease (Thind 2017). Manual and chemical weed control is expensive, laborious and time consuming (Thakur *et al.* 2012). There is huge pressure to reduce the use of herbicides in horticultural as well as other field crops. So, there is an urgent need to shift towards organic options for weed suppression in fruit crops. Among all the non-chemical methods of weed control, use of mulches helps to reduce weed infestation, maintains soil temperature, improves soil aeration and conservation of soil moisture and increase the soil fertility by addition of organic matter in orchards (Yao *et al.* 2005). Therefore, it was hypothesized that woven mulch mats of rice straw could be effective to manage weeds, enhances fruit yield and quality of papaya.

MATERIALS AND METHODS

Mulch mats of rice straw were developed in the Department of Apparel and Textile Science, Punjab Agricultural University, Ludhiana, (Kaur *et al.* 2020) with three variants of mulching and positioned in papaya orchard for weed management. Traditional *Adda* weaving technique was used to develop the woven mulch mats by using cotton yarn as warp and rice straw as weft. Paper making technique was used for developing non-woven mulch mats with 100% rice straw. Approximately 3- 3.5 kg of rice straw was used to prepare mulch mats of size of 70"x 40" which costed around ` 175/-. To study the effectiveness of these bio-degradable mulch mats, the experiment was conducted in collaboration with Department of Fruit Science at Fruit Research Farm, Punjab Agricultural University, Ludhiana, India during 2018-19 and 2019-20. The experimental area was situated in trans-gangetic agro-climatic zone, representing the Indo-Gangetic alluvial plains at 30^{o} 56' N latitude, 75^{o} 52' E longitude and at an altitude of 247 m above mean sea level. The region is characterized as sub-tropical semi- arid with hot summer and very cold winters. As papaya cv. *Red lady 786* is highly susceptible to the attack of pathogens, the experiment was conducted under well ventilated protected net house structure having 625 m^2 area of 25 m length, 25 m width and 4.5 m height. All sides of this net house were covered with 40 mesh insect net to protect crop against *'papaya ring spot virus'* disease. This net house was constructed with galvanized iron (GI) pipes entrenched in concrete pedestal structure.

The soil condition of papaya block at PAU, Ludhiana by the start and termination of experiment was sandy loam in texture, pH 8.1 and 8.0, organic carbon 0.24 and 0.26%, $CaCO_3$ 1%, electrical conductivity 0.20 mmho/cm, available phosphorous 20.1 and 20.4 kg/ha and potash 162.4 and 163.2 kg/ha, respectively. The seeds of papaya *cv. Red lady 786* were sown in 150 gauge thick transparent polythene bags (25 x 10 cm) containing solarized soil, sand and farmyard manure in equal proportions. Before sowing, the seeds of papaya *cv. Red lady 786* were treated with Captan 3 g/kg seed to avoid damping off of seedlings. The seedlings were transplanted after attaining a height of 15 cm above the ground level according to square system of planting at a density of 1.8 x 1.8 m under protected net house in the month of March 2018 and 2019. Three treatments of mulch materials included, woven mulch mats, non-woven mulch mats (both approximately 1cm thick) and loose rice straw 10.5 t/ha (6 cm thick) were placed after one week of transplanting papaya seedlings and compared with non- mulching area (control). Ten trees planted at 1.8 x 1.8 m covering an area of 32.4 m^2 (plot size 3.6 x 9.0 m) represented one replication. The experiment was laid out in randomized block design (RBD) with four treatments and five replications. Uniform cultural practices were followed in the whole experimental area. Soil application of fertilizers with 172.5 g nitrogen, 125 g phosphorous and 75g potassium each per plant were supplemented twice through urea, single super phosphate and muriate of potash, respectively, in February and August during both the years. Irrigation in the whole experimental block was done by the use of online drippers with a discharge frequency of 4 liters per hour. Water capacity was assessed according to pan evaporative value on daily basis.

The data on the efficacy of mulching material against weeds were recorded at an interval of 45 days starting from transplanting to harvesting of Papaya. The data on weed density was recorded from five quadrats in each plot of size 15 x 15 cm, at an interval of 45 days from transplanting of Papaya seedlings up to the fruit maturity (approximately 315 days) and expressed as number of weed plants/m^2. The data on broad-leaved weeds, grasses and sedges was taken according to *Rabi* and *Kharif* season weeds. Weed biomass was recorded by weighing above ground dry weight of weeds (oven-dried at 60±2°C for 72 hours) at the time of fruit maturity and expressed as g/m^2. The weed control efficiency (WCE) was also calculated based on dry weight of weeds.

The physico-chemical attributes of papaya fruits were recorded at the end of harvest. For this, 20 papaya fruits were analyzed per treatment with three replications. Plant height was measured with a measuring pole from the ground level to the top of the tree and expressed in meters. Weight of 20 papaya fruits was recorded with the help of digital weighing balance. Individual fruit weight was calculated and expressed in kilograms per fruit. Total number of fruits per tree was counted as fruit number. Fruit number multiplied with mean fruit weight was accounted as fruit yield and given as kg/tree. Titratable acidity was described in percentage of citric acid by using N/10 NaOH and phenol phthalein as indicator. The content of total carotenoids in the extract was determined by measuring the optical density of diluted sample. DPPH Radical Scavenging Activity was used to estimate Antioxidant Activity. The percentage of inhibition was calculated against blank: where, A blank is the absorbance of the control reaction (containing all reagents except the test compound) and A sample is the absorbance of the test compound.

$$I\% = \frac{\text{A blank - A sample}}{\text{A blank}}$$

The CIE lab values were examined, in which L measures lightness and it varies from 100 for perfect whiteness and zero for perfect black. The chromacity dimensions (a and b) give understandable designations of the colour as a- measures of redness when positive, grey when zero and greenness when negative; b- measures yellowness when positive, grey when zero and blueness when negative. The data were analyzed with SPSS version 22.0 (SPSS Inc., Chicago, Illinois) and significant differences (P = 0.05) between individual means were analyzed for analysis of variance (ANOVA) and subjected to mean comparison by using Duncan multiple range test.

RESULTS AND DISCUSSION

Weed flora

During this investigation, *Chenopodium album, Oxalis corniculata, Gnaphalium purpureum, Rumex dentatus, Coronopus didymus, Launea asplenifolia, Phyllanthus niruri, Cyperus rotundus, Digitaria sanguinalis, Panicum colonum, Cynodon dactylon, Acrachne racemosa* and *Eragrostis tenella* were the different weeds documented at the experimental location. In India, presence of weeds in the field crops resulted in 45% produce loss (Rao 1983). In horticultural crops, the yield losses due to the weeds were reported from 34.0 to 71.7% (Leela 1993). This loss varies according to the nature of diverse weed flora and fruit crops (Abouziena *et al.* 2016). Weeds have competition along with the orchard crops for nutrients, water and they also act as alternate host for incidence of insects and diseases (Futch and Singh 2011). Weed roots also secrete toxins, adversely affecting the vegetative growth and causes loss in yield and quality of fruits (Singh 2000). Weed competition causes a negative impact on the trunk diameter, leaf weight and metabolism in apples (Merwin and Stiles 2016). Therefore, the weed management is a major challenge for the fruit growers especially for papaya growers as it being shallow rooted crop could encounter herbicidal phytotoxicity.

Weed control

In papaya orchard, woven mulch mats resulted in significant reduction in weed density as compared to non- woven mulch mats, loose rice straw and control (**Table 1**). The life span of woven mulch mats has been recorded as one year in the experimental area and the decomposition of the woven mulch mats started thereafter. As papaya has a short span of 11 months, these woven mulch mats were found effective to control the weeds starting from the transplanting of crop up to the fruit harvest period under the protected structure. These woven mulch mats acted as surface barrier to control broad-leaved weeds and sedges (**Table 2**) and also grasses (**Table 3**) for the entire vegetative growth period and fruiting season. Non-woven mulch mats and loose rice straw also proved to be significantly effective to control the diverse weed flora as compared to control (bare soil). However, both of these have to be replaced after a period of 140 days from transplanting of the papaya crop due to their decomposition. No significant difference was recorded between non- woven mulch mat and loose rice straw against weeds as well as for their time of decomposition in papaya orchard field.

Table 1. Effect of woven mulch mats on total weed density at different stages in papaya (pooled data of 2018-19 and 2019-20)

Treatment	Weed density (no./m^2)						
	45 Day	90 Day	135 Day	180 Day	225 Day	270 Day	315 Day
Woven mulch mats	1.39 (1)	1.99 (3)	2.23 (4)	2.23 (4)	2.23 (4)	2.45 (5)	2.31 (4)
Non -woven mulch mats	3.60 (12)	3.99 (15)	4.12 (16)	4.24 (17)	4.24 (17)	4.36 (18)	4.40 (18)
Loose rice straw	3.74 (13)	3.87 (14)	4.12 (16)	4.35(18)	4.47 (19)	4.69 (21)	4.38 (18)
Control	9.38 (87)	11.04 (121)	11.53 (132)	12.08 (145)	12.37 (152)	12.41 (153)	10.00 (99)
LSD (p=0.05)	0.24	0.24	0.18	0.21	0.21	0.2	0.41

Original data given in parenthesis was subjected to square root $(\sqrt{x+1})$ transformation before subjecting to statistical analysis

Table 2. Effect of woven mulch mats on weed density of broad leaf weeds and sedges, and total dry matter after 315 days of planting in papaya ((pooled data of 2018-19 and 2019-20)

Treatment	Weed density (no./m^2)								Total weed biomass (g/m^2)
	Broad-leaved weeds							Sedge	
	Chenopodium album	*Oxalis corniculata*	*Gnaphalium purpureum*	*Rumex dentatus*	*Coronopus didymus*	*Launaea asplenifolia*	*Phyllanthus niruri*	*Cyperus rotundus*	
Woven mulch mats	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.72 (2)	1.72 (2)	1.32 (2.74)
Non-woven mulch mats	1.39 (1)	1.0 (0)	1.0 (0)	1.72 (2)	1.39 (1)	1.99 (3)	1.99 (3)	2.99 (8)	2.60 (5.78)
Loose rice Straw	1.39 (1)	1.39 (1)	1.41 (1)	2.23(4)	1.39 (1)	1.41 (1)	1.72 (2)	2.82 (7)	2.81 (6.91)
Control	3.0 (8)	2.64 (6)	2.23 (4)	3.31 (10)	3.31 (10)	3.99 (15)	4.12 (16)	5.57 (30)	7.70 (58.3)
LSD (p=0.05)	0.28	0.22	0.11	0.26	0.29	0.24	0.29	0.27	0.07

Original data given in parenthesis was subjected to square root $(\sqrt{x+1})$ transformation before subjecting to statistical analysis

Table 3. Effect of woven mulch mats on weed density of grasses in papaya (pooled data of 2018-19 and 2019-20)

Treatment	Weed density (grasses) (no./m^2)				
	Digitaria sanguinalis	*Panicum colonum*	*Cynodon dactylon*	*Acrachne racemosa*	*Eragrostis tenella*
Woven mulch mats	1.0 (0)	1.41 (1)	1.0 (0)	1.0 (0)	1.0 (0)
Non- woven mulch mats	1.41 (1)	1.39 (1)	1.39 (1)	1.0 (0)	1.41 (1)
Loose rice straw	1.72 (2)	1.39 (1)	1.39 (1)	1.39 (1)	1.39 (1)
Control	2.99 (8)	3.6 (12)	1.72 (2)	4.79 (22)	4.35 (18)
LSD (p=0.05)	0.16	0.33	0.30	0.23	0.23

Original data given in parenthesis was subjected to square root $(\sqrt{x+1})$ transformation before subjecting to statistical analysis

All the treatments reduced the total weed biomass as compared to control in papaya crop. Application of woven mulch mats resulted in minimum total weed biomass followed by non-woven mulch mats and loose rice straw mulch treatment up to 315 days of Papaya seedling transplanting (**Table 2**).

The results of a study by Huystteen and Weber (1980) revealed that the yield and quality of grapes was highest with the use of straw mulch in comparison to clean cultivation which led to significant competition for water and nutrients. Another study by Grieshop *et al.* (2012) suggested that wheat straw and spoiled hay were beneficial in reducing weeding time as compared to using wood mulches or using burlap sacks.

Biodegradable mulches can be used as an alternative to synthetic plastic mulches, which are used to improve soil moisture status along with providing weed control (Girgenti *et al.* 2012). If the ingredients of the mulch are permitted, use of such mulch could be desirable as it would not require its removal/ disposal. A study by Benoit *et al.* (2006) elicited that use of biodegradable cellulose mulch provided good weed control in the first year, but lasted only for one year and needed to be replaced for supplying ongoing weed control. Biodegradable manufactured mulches degrade through weathering, ultraviolet radiation exposure and microbial degradation. This material leads dead organic mulch, which enhances control of weeds by suppression and also by curtailing re-generation and subsequent germination in flushes. The maximum weed control efficiency (95.3%) was recorded with woven mulch mats followed by non-woven mulch mats in Papaya orchards (**Figure 1**).

Physico-chemical attributes

All the physico-chemical characters of the papaya plants improved significantly with woven mulch mats as compared to all other treatments (**Table 4**). Plant height increased significantly with woven mulch mats as compared to all other treatments. Fruit number/tree was recorded to be non- significant among different treatments. The weight of papaya fruits (26.3%) was significantly higher with woven mulch mats as compared to

Table 4. Effect of woven mulch mats on physical and biochemical attributes in papaya (pooled data of 2018-19 and 2019-20)

Treatment	Plant height (cm)	Fruit weight (kg/fruit)			Fruit number	Fruit yield (kg/tree)			TSS (^{0} brix)	Acidity (%)	Carote-noids (µg/g)	Antioxi-dants (%)
		2018-19	2019-20	Pooled		2018-19	2019-20	Pooled				
Woven mulch mats	289	1.23	1.27	1.25	48	57.81	62.23	60.0	11.0	0.67	10.79	89.92
Non- woven mulch mats	274	1.17	1.00	1.09	46	55.28	45.00	50.14	11.0	0.74	9.19	86.74
Rice straw mulch	266	1.10	1.06	1.08	45	48.40	48.76	48.60	9.5	0.79	7.36	86.11
Control	250	1.02	0.97	0.99	46	47.43	43.65	45.54	10.0	0.84	6.57	76.52
LSD (p=0.05)	14	0.09	0.13	0.09	NS	5.1 0	8.5 0	5.42	0.65	0.06	1.64	5.01

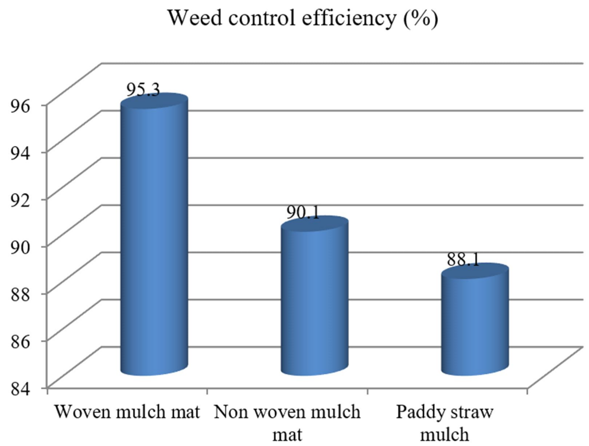

Figure 1. Weed control efficiency of different rice straw mulch treatments

control. Fruit yield (31.7%) also increased significantly with woven mulch mats as compared to control. The results are in agreement with Duppong *et al.* (2004) who also reported increase in yield of catnip by the use of flax straw mat (1.2 cm thickness) for weed management. TSS, carotenoids and antioxidants of papaya fruits were also improved significantly with woven mulch mats as compared to control. Whereas, acidity was recorded to be significantly lower with woven mulch mats as compared to control. It was found that the colour of the fruit was more appealing in case of woven and non-woven mulch mats as compared other two treatments (**Table 5**).

Rice straw mulch effectively controlled weeds in citrus groves (Abouziena *et al.* 2008) and weed free environment with negligible weed competition improved fruit yield and quality of *Kinnow* fruits. Tree productivity (weight of mandarin fruits per tree) was also improved as a result of effective weed control (Abouziena *et al.* 2008). The results indicated that the use of woven mulch mats at the time of transplanting of seedlings provided better and effective control of diverse weed flora in papaya orchard during the entire life span as compared to other treatments. Moreover, this treatment resulted in enhanced tree productivity in terms of fruit quality and quantity of papaya crop.

Table 5. CIE lab values of the papaya fruits

Treatment	L*	a*	b*
Woven mulch mats	50.22	35.35	47.09
Non-woven mulch mats	47.03	27.52	45.48
Rice Straw mulch	54.59	24.38	53.75
Control	57.56	24.31	56.87

L*measures lightness, a* is chromaticity dimension (red) and b* is chromaticity dimension (yellow)

Conclusion

It may be concluded that woven mulch mats might be popularized for effective weed control in papaya. Since rice burning has become a menace, utilizing rice straw for various purposes will not only help to curb this problem but will also help entrepreneurs to raise income for better livelihoods of rural population. This may also give impetus for developing R&D programmes suitable for small scale industries. Rice straw woven mulch effectively controlled weeds in papaya throughout its growing cycle and improved fruit yield and quality. Therefore, such an alternative should be encouraged in Papaya and other orchards as well.

ACKNOWLEDGEMENTS

We acknowledge our sincere thanks to Central Institute of Women in Agriculture, Bhubaneswar for the encouragement and financial support extended for the project.

REFERENCES

Abouziena HF, Hafez OM, El-Metwally IM, Sharma SD and Singh M. 2008. Comparison of weed suppression and mandarin fruit yield and quality obtained with organic mulches, synthetic mulches, cultivation, and glyphosate. *Hort Science* **43**: 795–799.

Abouziena HF, Haggag WM, El-Saeid, HM and El-Moniem A. 2016. Safe methods for weed control in fruit crops: Challenges and opportunities: Review. *Der Pharmacia Lettre* **8**: 325–339.

Anonymous. 2010. Large scale testing of precision farming technologies in papaya. pp 85–89. In: *Report of 6th Meeting of Natural Resources Management Joint Sub Committee*, 6- 7 April 2010.

Anonymous. 2019. The Adverse effects of stubble burning on our environment, https://www.aqi.in/blog/stubble-burning-and-its-impact-on-the-environment/, 5th February 2019.

Benoit LD, VincentC and Chouinard G. 2006. Management of weeds, apple sawfly (*Hoplocampatestudinea* Klug) and plum curcuclio (*Conotrachelus nenuphar* Herbst) with cellulose sheeting. *Crop Protection* **25** (4):331–337.

Duppong LM, Delate K, Liebman M, Horton R, Romero F, Kraus G, Petrich J, and Chowdbury PK. 2004. The effect of natural mulches on crop performance, weed suppression and biochemical constituents of catnip and St. John's Wort. *Crop Science* **44**(3): 861–869.

Futch SH and Singh M. 2011. Weeds In: Rogers M. E., Dewdney, M. M., Spann, T. M (eds.) *Florida Citrus Pest Management Guide*. University of Florida, IFAS, Gainesville.

Girgenti V, Cristiana P, Giuggioli N, Giraudo E and Guerrini S. 2012. First results of biodegradable mulching on small berry fruits. *Acta Horticulturae* **926**: 571–576.

Jitendra, Venkatesh S, Kukreti I, Pandey K, and Mukerjee P. 2017. India's burning issue of crop burning takes a new turn. https://www.downtoearth.org.in/coverage/india/river-of-fire-57924, 31 May 2017.

Kaur R, Bains S and Sethi M. 2020. Environment-friendly mulch mats from rice straw. *International Journal of Farm Sciences* **10**(2): 28-31.

Leela D. 1993. Present status and future scenario of weed control in horticultural crops. Golden Jubilee Symposium, "*Horticultural Research-Changing Scenario*", at Banglore, Karnataka, 1993.

Grieshop MJ, Eric Hanson, Annemiek Schilder, Rufus Isaacs, Dale Mutch, Carlo Garcia, Salazar, Mark Longstroth, Jesse Sadowsky (2012) Status update on organic bluberries in Michigan. *International journal of Fruit Science* **12**: 232–245

Merwin IA and Stiles WC. 2016. Orchard ground cover management impacts on apple tree growth and yield, and nutrient availability and uptake. *Journal of American Society for Horticultural Science* **119**: 209–215.

Rao VS. 1983. *Principles of Weed Science*. Oxford and I.B.H. Publication company, New Delhi

Singh PS. 2000. *Effect of post-emergence herbicides on weed control in Kinnow orchard*. Thesis Punjab Agricultural University, Ludhiana.

Suresh R. and Saha, DP. 2004. Effect of mulching and drip irrigation on papaya in calcareous soil of North Bihar. *Progressive Horticulture* **36**(1): 76–81.

Thakur A, Singh H, Jawandha S and Kaur T. 2012. Mulching and herbicides in peach: weed biomass, fruit yield, size and quality. *Biological Agriculture & Horticulture* **28**: 280–290.

Thind SK. 2017. Principles of disease management in fruit crops. *International Clinical Pathology Journal* **4**: 123–137.

Huystteen VL and Weber HW. 1980. The effect of selected minimum and conventional tillage practices in vineyard cultivation on vine performance. *South African Journal of Enology and Viticulture* **1**: 77–83.

Yao S, Merwin IA, Bird GW, Abawi GS and Thies JE. 2005. Orchard floor management practices that maintain vegetative or biomass groundcover stimulate soil microbial activity and alter soil microbial community composition. *Plant Soil* **271**: 377–389.